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Abstract **– The study of the transport of electrons, and the flow of energy into a solid target or dense plasma, is instrumental in the development of fast ignition inertial confinement fusion. An extreme ultraviolet (XUV) imaging diagnostic at 256 eV and 68 eV provides information about heating and energy deposition within petawatt laser-irradiated targets. XUV images of several irradiated solid targets are presented.**

Index Terms **– Fast ignition, multilayer optics, XUV imaging.**

In the fast ignition [1] approach to inertial confinement fusion (ICF), a fusion target of deuterium and tritium fuel is first compressed to a high density by the use of a laser drive pulse (10s of ns), and then a second, much shorter (~10 ps) high intensity laser pulse generates a high current electron beam at the edge of the cold, highly compressed plasma. The electron beam then heats a localized region to fusion temperatures, which sparks a burn wave able to propagate throughout the remainder of the pellet, as a result generating fusion energy. An advantage of this scheme as compared to conventional ICF is that the compression and heating phases are separate, which relaxes constraints for the initial compression. However, many issues still need to be explored, including how the electrons are transported and what the spatial distribution of energy within the target is.

The interaction of an ultra-intense laser with a solid target generates a large flux of energetic electrons that then heat the material, resulting in a Planckian emission spectrum extending into the extreme ultraviolet (XUV). This emission peaks as the electrons couple their energy to the lattice, then radiatively cools [2]. Because radiation intensity varies so rapidly with temperature and the very short absorption length in the XUV, time integrated imaging of this radiation offers an excellent tool to measure the maximum surface temperature of dense plasma targets.

The XUV imaging diagnostic collects light within a solid angle determined by an aperture and relays this to a charge-coupled device (CCD) via two multilayer XUV mirrors that dictate what energy bandwidth is reflected. Two channels of the XUV diagnostic were run: one optimized for 68 eV light, and the other for 256 eV light. By running two different channels imaging at slightly different energies, insight can be gained about the heating, expansion and cooling characteristics of the target (because these energies are collected from different depths within the plasma), as well as allow for verification of thermal temperatures derived from the diagnostic.

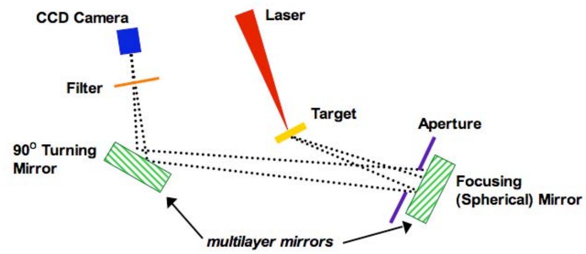

Fig. 1. A schematic of the XUV imaging diagnostic setup.

The 68 eV mirrors are a Mo_2C/Si multilayer, while the 256 eV mirrors are a C/WC/Monel/W formula. These alternating layers of high and low indices of refraction allow for the constructive interference of x-rays to increase overall mirror reflectivity [3]. Each XUV channel uses a pair of multilayer mirrors specifically manufactured to have matching spectral reflectivity. Pairing the mirrors also results in squaring the contrast against the background, while additionally allowing the detector to be kept out of the straight line of hard hits. The spherical mirrors have a radius of curvature of 0.5 m, and are placed approximately 0.27 m away from the target being imaged such that target backside emission is reflected off the mirror. This emission is then projected onto the second multilayer (the plane mirror) at a path length of approximately 2.15 m, where it is deflected 90º, then goes through a filter, before reaching the CCD (see

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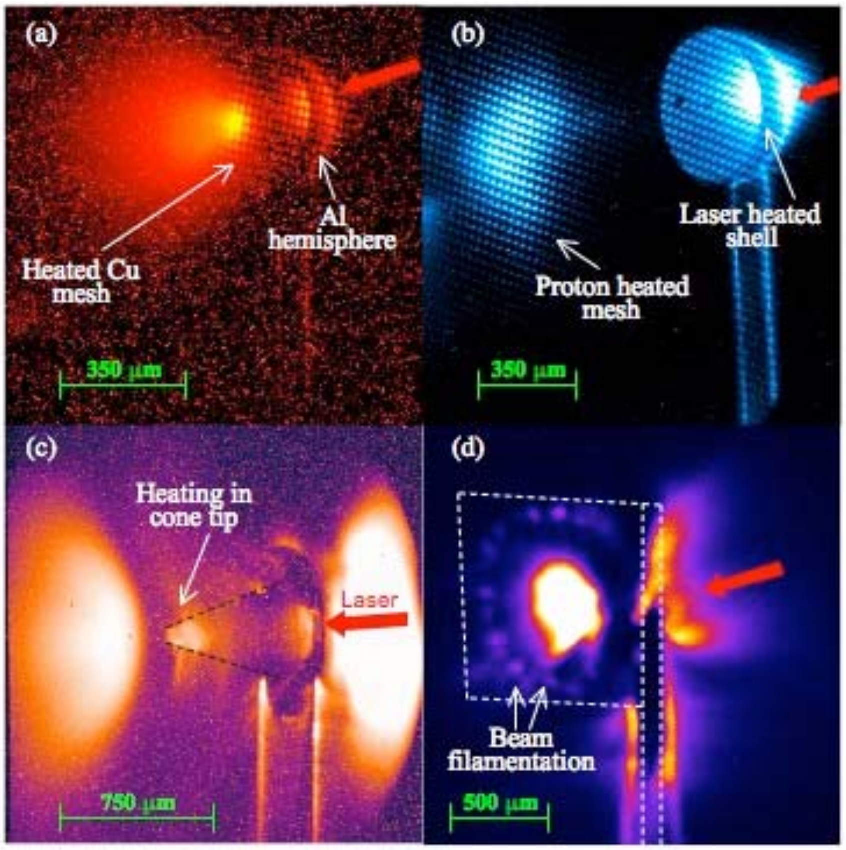

Fig. 2. (a) A 256 eV image of a half sphere with a grid 228 µm behind it. (b) A 68 eV image of a half sphere with a grid 804 µm behind it. (c) A 68 eV image of a copper cone. (d) A 68 eV image of a 10 µm CD/ 5 µm Al/ 10 µm CD sandwich.

Fig. 1a). The filter is thin aluminum and polyimide, and designed to protect the CCD from visible and UV light. Princeton Instrument PI-SX:1300 CCD cameras record the images with a resolution of 20 µm. The total magnification is approximately 11, and a 6 mm aperture in front of the spherical mirror gives a collection solid angle of $5.2\text{x}10^{-4}$ sr.

The XUV system was used to image a variety of targets that were irradiated with the Titan Laser at the Lawrence Livermore National Laboratory. The laser generates pulses of 500 fs duration, spot size of 8 µm, and an energy of 150 J, for a total intensity on target of approximately $6\text{x}10^{20}$ Wcm^{-2}. These targets included metallic and plastic flat foils, copper hemispheres and copper cones. XUV images of these targets show the location of the interaction region, the thermal distribution of electrons, spatial features of the plasma plumes and any filamentation of the electron beams. Fig. 2a shows a 256 eV image of a 20 um thick Al hemisphere of radius of curvature of 175 µm with a grid placed 228 µm behind it. This image can be compared against the 68 eV image for a similar hemisphere but with a grid placed 804 µm behind in Fig. 2b. A cone shot head on in Fig. 2c shows the expanded plasma plume in the cone open end and the blowoff plasma from the cone tip. Also of interest is the concentration of energy in the cone tip. The XUV is singular in that it can very clearly capture beam filamentation when it occurs, as in the case for Fig. 2d, a 10 µm CD/ 5 µm Al/ 10 µm CD target. In this shot, the center spot is due to direct heating of the target from the laser, while the smaller spots in the ring are electron beams that have filamented while traveling through the low-density plasma.

In conclusion, time-integrated, high spatial resolution extreme ultraviolet images of targets heated by a petawatt laser have been presented. The heating of these targets and consequent plasma expansion is captured to give a view of the electron transport.

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